

Controlling Single-Molecule Motion at Surfaces

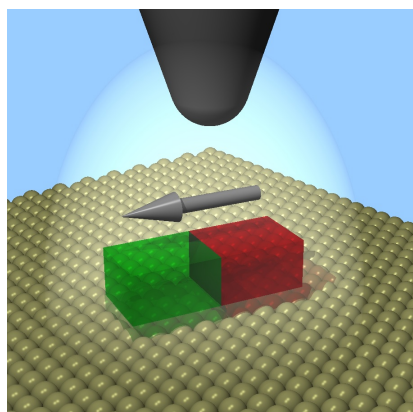
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Studying single-molecule motion at single-crystal surfaces holds various advantages: (i) highly defined potential landscapes of flat and stepped surfaces with specific chemical properties, (ii) directly visualization of single molecules and their pathways by scanning probe microscopy, (iii) manipulation to induce chemical processes (including motion) in a controlled way with the microscope tip, (iv) two-dimensional confinement of the motion and thus the possibility to follow single-molecule trajectories, and (v) identification of surface defects and thus control over the atomic-scale surroundings of each molecule.

In this presentation, various cases of mobile molecules at surfaces, studied by scanning tunneling microscopy (STM), will be discussed. The chemical structure of the molecule defines preferential orientations and directions of motion. Weak adsorption is advantageous for



efficient motion, which could be achieved by specific molecular side groups [1]. The same molecules can also be rotated with 100% directionality via an electric dipole in the molecule (as sketched in the figure) [2], even allowing to map the electric dipole of the molecule via the molecular response to the applied field. For azobenzene switching units in a tetrahedral arrangement not only reversible photo-isomerization for the upright standing unit is found, due to decoupling, but also isomer-dependent diffusion on the surface is observed [3]. On the other hand, by incorporating

isomerization-based molecular ‘Feringa’ motors, photo-enhanced and wavelength-sensitive translation of molecular machines is observed on a metal surface [4]. Importantly, the light does not change the *number* of moving molecules, but their lateral *displacement*.

- [1] G. J. Simpson et al., *Nature Nanotech.* 12, 604 (2017); [2] G. J. Simpson et al., *Nature Comm.* 10, 4631 (2019); [3] C. Nacci et al., *Angew. Chem. Int. Ed.* 57, 15034 (2018); [4] A. Saywell et al., *ACS Nano* 10, 10945 (2016)